Abundance, size distribution and habitat preferences in the grouper assemblage of the Ustica marine reserve (SW Mediterranean)

by

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ABSTRACT. - The abundance and size distribution of groupers during summer were assessed along the shores of an islet (Scoglio del Medico) in the Ustica marine reserve. The relationships between grouper distribution and some micro and macrohabitat characteristics were also evaluated. The dusky grouper *Epinephelus marginatus* (Lowe, 1834) was the most common species and showed a well structured population. This species displayed a clear pattern of variation in density during summer, with peak abundance occurring in July and August. The goldblotch grouper *Epinephelus costae* (Steindachner, 1878) and the mottled grouper *Mycteroperca rubra* (Bloch, 1793) were the other resident species and their density varied markedly depending on sampling period. Both *E. costae* and *M. rubra* were mainly recorded in the western sectors of the islet, which were the most exposed to the prevailing wave direction. The dusky grouper sample was numerically dominated by medium sized individuals, whereas juveniles were not very common, likely due to the absence of sheltered sites along the islet coastline. A shift of groupers toward deeper waters with increasing size was observed both in *E. marginatus* and *E. costae*, whilst no significant differences were detected in the size frequency distribution with depth of *M. rubra*. The bulk of dusky grouper was observed resting on or close to bottom. Conversely, both *E. costae* and *M. rubra* dwelled preferentially far from bottom. The kind of reaction of groupers to diver seemed to have no relationship with fish size. At microhabitat level, *E. marginatus* preferred rocky reef areas with dense algal cover and high complexity. Conversely, neither *E. costae* nor *M. rubra* appreciated uneven substrata, likely in relation to their benthopelagic habit. In terms of macrohabitat, only *M. rubra* showed specific requirements, preferring gently sloping plateau.

RÉSUMÉ. - Abondance, distribution des tailles et préférences d'habitat des mérous de la réserve marine d'Ustica (Méditerranée nord-occidentale).

L'abondance et la distribution des tailles des mérous ont été étudiées pendant l'été le long des rivages d'un îlot (Scoglio del Medico), dans la réserve marine d'Ustica (Méditerranée nord-occidentale). La relation entre la distribution des mérous et quelques caractéristiques du micro- et du macrohabitat a été aussi estimée. Le mérou brun *Epinephelus marginatus* (Lowe, 1834) est l'espèce la plus commune et montre une population bien structurée. Cette espèce manifeste un modèle clair de variation de densité, avec un maximum d'abondance en juillet et en août. La densité des autres espèces résidantes, la badèche *Epinephelus costae* (Steindachner, 1878) et la badèche rouge *Mycteroperca rubra* (Bloch, 1793) a considérablement changé avec la période d'échantillonnage. Elles ont été trouvées principalement dans la région occidentale de l'île, qui est la plus exposée à la direction prédominante des vagues. L'échantillon des mérous bruns était dominé par les individus de taille moyenne, les juvéniles n'étaient pas communs, probablement à cause du manque de refuges disponibles. *E. marginatus* et *E. costae* se déplacent en profondeur avec leur accroissement en taille, à l'inverse de *M. rubra* qui ne présente pas de différence significative de distribution des tailles avec la profondeur. La plupart des mérous bruns ont été observés sur ou à proximité du fond. Au contraire, *E. costae* et *M. rubra* résident préférentiellement loin du fond. Il n'y a eu aucun lien entre la réaction des mérous aux plongeurs et la taille des poissons. *E. marginatus* préfère un microhabitat caractérisé par des zones rocheuses complexes avec une couverture dense d'algues. Au contraire, *E. costae* et *M. rubra* n'apprécient pas ce type de substrats irréguliers, probablement car ils ont un comportement bentho-pélagique. Pour le macrohabitat, seul *M. rubra* a montré des exigences particulières puisque cette espèce préfère des fonds avec une légère pente.

Key words. - Serranidae - *Epinephelus marginatus* - *E. costae* - *Mycteroperca rubra* - MED - Ustica marine reserve - Size structure - Micro and macrohabitat.

Groupers (Serranidae: Epinephelinae) are important top-level predators both in temperate and tropical waters, where they play an important role in maintaining the ecological balance of marine ecosystems (Goeden, 1982; Parrish, 1987). A number of grouper species have experienced marked decline in abundance, size, landings and catch owing to severe exploitation (Sadovy, 1994; Gracia, 1996; Morris *et al.*, 2000). Moderate to large species are particularly vulnerable to intense fishing because of their longevity, slow growth, delayed reproduction and aggregate spawning behaviour. The protection measures in force within marine reserves, i.e. areas permanently closed to consumptive use, offer a viable means to protect grouper resources (Russ and Alcala, 1996; Sluka *et al.*, 1997; Beets and Friedlander, 1998). Due to the benefits resulting from the environmental protection, in some marine protected areas grouper populations became abundant and well structured (Chauvet *et al.*, 1991; Harmelin *et al.*, 1995; Zabala *et al.*, 1997a; Reñones *et al.*, 1999;

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Cybium 2006, 30(4): 365-377.

Chiappone *et al.*, 2000). Several studies have dealt with the habitat preferences of groupers in coral reef areas (Thompson and Munro, 1978; Nagelkerken, 1979; Parrish, 1987; Shpigel and Fishelson, 1989; Beets *et al.*, 1994; Sluka *et al.*, 1996). These studies demonstrated that grouper assemblage may differ significantly both among different coral reef and, at smaller spatial scale, among different habitats or zones of the same reef. In most cases, species-specific relationships between some habitat features of coral reefs and grouper abundance have been indicated as the main factor in determining the observed pattern of variation. For Parrish (1987), the habitat choice of tropical groupers was more strictly related to the need for shelter than for food.

Current information indicates groupers as secretive fish, inhabiting preferentially shelter-rich sites of littoral rocky bottoms (Smith, 1961; Heemstra and Randall, 1993). In some species, a depth-related habitat shift during the ontogenesis has been reported. Juveniles were more frequently associated to nearshore habitats than adults and larger adults occurred preferentially in deeper waters than the smaller ones (Thompson and Munro, 1978; Derbal and Kara, 1995; Francour and Ganteaume, 1999; Harmelin and Harmelin-Vivien, 1999; Harmelin and Robert, 2001).

All but one of the native species of grouper inhabiting the Mediterranean waters belong to the genus *Epinephelus*. The most abundant and frequent species is the dusky grouper *Epinephelus marginatus* (Lowe, 1834), which dwells on coastal rocky bottoms on the continental shelf, preferentially down to 50 m depth (Heemstra and Randall, 1993). The mottled grouper *Mycteroperca rubra* (Bloch, 1793) and the goldblotch grouper *Epinephelus costae* (Steindachner, 1878) are relatively common species, at least in the southern Mediterranean basins. They can be found on rocky and sandy bottoms, from few meters to 200-300 m depth (Tortonese, 1986; Heemstra and Randall, 1993). Literature data on the habitat requirements of *E. marginatus* have been reviewed by Harmelin and Harmelin-Vivien (1999). Despite the large amount of studies on this topic, the preference of dusky grouper has been exclusively evaluated in relation to some macrohabitat features, such as depth, bottom slope and topography (Chauvet, 1991; Derbal and Kara, 1995; Francour and Ganteaume, 1999; García-Rubies *et al.*, 1999; Mathieu-Tissot, 1999; Vacchi *et al.*, 1999; Bodilis *et al.*, 2003a, 2003b). More recently, some information has been collected on the microhabitat preference of juveniles dusky grouper (La Mesa *et al.*, 2002).

In the marine reserve of Ustica Island (southern Thyrrhenian Sea), the presence of *E. marginatus, E. costae* and *M. rubra* was firstly assessed by a pluriannual monitoring programme on the fish assemblage (La Mesa and Vacchi, 1999). Further studies highlighted the positive effect of environmental protection on grouper size and density, especially in *E. marginatus* and *E. costae* (Vacchi *et al.*, 1999). Around the island, some sites of primary interest in terms of grouper aggregation were identified. The most representative of these sites is Scoglio del Medico, a small islet located off the northern coast of Ustica. The aim of the present work was to quantify the relative abundance and size distribution of *E. marginatus, E. costae* and *M. rubra* around Scoglio del Medico, and to evaluate the relationships between grouper distribution and some micro and macrohabitat characteristics.

MATERIAL AND METHODS

Study area

The small volcanic island of Ustica (8 km^2) is located 36 miles off the north-western coast of Sicily (SW Mediter-

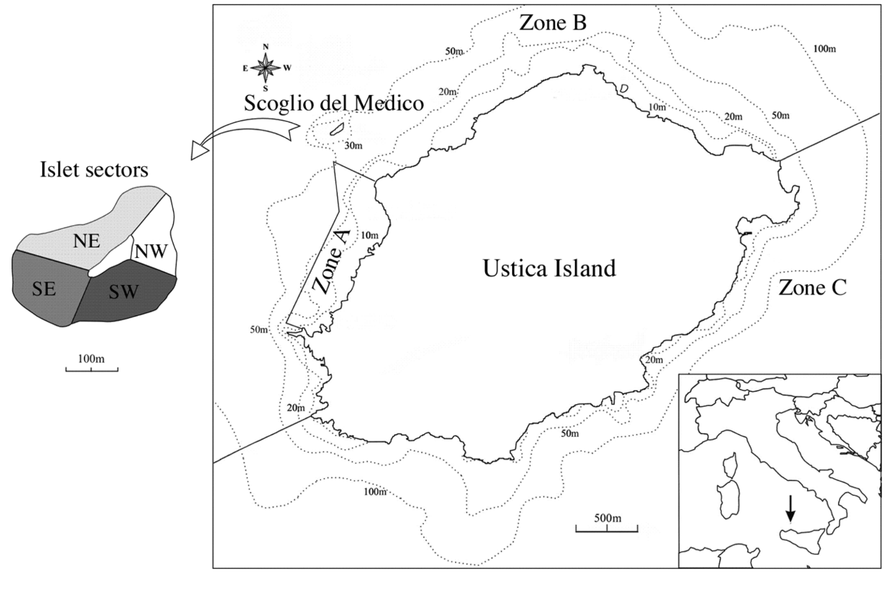


Figure 1. - Location of the study area and of sampling sectors around the Scoglio del Medico islet. *[Localisation de la zone d'études et des secteurs échantillonnés le long de l'îlot Scoglio del Medico.]*

Table I. - Summary of variables describing micro and macrohabitat characteristics. *[Résumé des variables qui décrivent les caractéristiques des micro- et macrohabitats.]*

Set of variables	Variable code	Variable category		
		1	2	3
Microhabitat scale				
Depth (m)	DEP	0-13.9	14-21.9	22-30
Concavity/convexity	CAV	concave	flat	convex
Cavity orientation	ORI	upward	downward	-
Complexity (height of relief)	COM	low (< 10 cm)	high (> 10 cm)	-
Bare rock	ROC	< 50%	> 50%	-
Small turf algae (< 3 cm)	STA	< 50%	> 50%	-
Long turf algae (> 3 cm)	LTA	< 50%	> 50%	-
Sponges	SPO	present	-	-
Macrohabitat scale				
Bottom slope (°)	SLO	0-60	> 60	-
Rocky plateau	PLA	< 50%	> 50%	-
Boulders	BOU	< 50%	> 50%	-
Sheltering degree	SHD	low	medium	high

ranean). The marine reserve of Ustica, which comprises the entire island coastline and extends offshore for 3 nautical miles, is divided in three zones of raising level of protection (Zones C, B and A of partial, general and integral reserve, respectively) (Fig. 1). Sampling activities were carried out within the general reserve (Zone B) all around the coast of Scoglio del Medico, a small islet (260 m perimeter) of basaltic rock located about 0.3 miles from the shore. The islet has a roughly rectangular-shaped contour, with each coast characterized by different bottom topography and exposure to dominant wave direction. The south-eastern coast is the most sheltered, being opposite the main island, and is characterized by a gently sloping rocky bottom to 10-12 m depth. Beyond this depth the bottom drops abruptly to 25-30 m depth, where huge boulders rest on sandy bottom. In the south-western coast, which is frequently exposed to hydrodynamism, some rocky ridges and canyons are followed offshore by large boulders covered by algal canopy. The north-western coast faces similarly toward the prevailing wave direction and is characterized by a rocky plateau to 12 m depth, where it is replaced by a steep bottom with large boulders. In the north-eastern coast, which is moderately exposed, the bottom topography is quite different. A vertical rocky cliff extending from the coastline to 20-25 m depth is followed by a gently sloping sandy bottom with very large boulders. The sampling area stretched from the shoreline of the islet to 30 m depth (about 0.06 km^2) and was divided into four sectors, corresponding to the islet coasts. A Geographic Information System (GIS) map of the area around the islet was analyzed by Archinfo package in order to roughly estimate the area surveyed at each sector.

Species	Year	Month	Coast				Total
			SW (15.0)	SE (15.8)	NE (9.0)	NW (18.2)	
Epinephelus marginatus	2002	June	15	11	3	7	36
		July	5	16	8	14	43
		August	12	14	7	12	45
		September	12	7	2	8	29
Epinephelus costae	2002	June	8	1	8	4	21
		July	9	4	1	3	17
		August	9	0	2	2	13
		September	2	1	0	2	5
Mycteroperca rubra	2002	June	0	0	0	0	0
		July	3	0	0	3	6
		August	4	0	0	0	4
		September	0	0	0	2	2
Epinephelus marginatus	2003	June	5	3	5	6	19
		July	14	15	10	3	42
		August	11	13	4	5	33
		September	8	10	5	10	33
Epinephelus costae	2003	June	4	2	1	2	9
		July	2	1	0	1	4
		August	7	0	0	3	10
		September	1	3	1	1	6
Mycteroperca rubra	2003	June	2	0	1	11	14
		July	4	0	0	4	8
		August	0	1	0	9	10
		September	2	0	0	5	7

Table II. - Number of groupers observed in the sampling periods for each sector of the islet. The surveyed area (x 10^3 m^2) per sector is in parentheses. *[Nombre de mérous observés pendant les périodes de recensement pour chaque côte de l'îlot. La zone d'échantillonnage par secteur (x 10^3 m^2) est entre parenthèses.]*

Data collection

The grouper assemblage was surveyed monthly during summer (from June to September) 2002 and 2003. Visual censuses were conducted by means of SCUBA dives, in the morning and with good sea-weather conditions. Prior to field observations, divers were trained to accurately estimate fish size. To count fish, each sector of the islet was divided into stretches parallel to shore and different in width, depending on bottom topography. Starting from the deepest stretch, the diver swam slowly above the bottom along the stretches describing accurately each grouper sighting according to a standard protocol. Some fish characteristics, such as size (total length, TL), colour pattern, reaction to diver (escape, unconcern or attraction) and position (distance from the bottom) were recorded. The colour patterns of *Epinephelus marginatus* was assessed according to the description of Zabala *et al*. (1997a). The habitat characterization of the sites where still or swimming fishes were firstly sighted was accomplished by using both biotic and abiotic variables, ranked in ordered categories (Tab. I). Taking into account the strong sedentary behaviour of juvenile grouper, we chose to focus on the habitat characterisation at two spatial scales. At small spatial scale (a circle with a diameter of 60-80 cm centred on the fish), some microhabitat features concerning substrate morphology and type of cover were recorded. Substratum complexity was visually evaluated on the basis of height of relief. The presence of cavities along with the concavity orientation were also recorded. On large spatial scale (a circle with a diameter of 6-8 m), macrohabitat was characterized in relation to bottom topography and composition. The sheltering degree of the environment surrounding the fish was defined as low, medium or high depending on the presence and number (one or more) of vertical or overhanging rockwalls.

Table III. - Results of chi-square analyses testing for inter and intraspecific differences in grouper abundance in relation to year, month (within year) and coast (within year). Significance level: ns = no significant differences $p \geq 0.05$, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$. *[Résultats de l'analyse du χ^2 testant les différences inter- et intraspécifiques en fonction de l'année, du mois (pendant l'année) et de la côte (pendant l'année). Significativité: ns= non-significatif à $p = 0,05$, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.]*

Species	Year	Month		Coast	
		2002	2003	2002	2003
Among species	23.74 ***	11.38 n.s.	13.18 *	15.81*	36.77 ***
Epinephelus marginatus	2.41n.s.	4.15 n.s.	8.53 *	2.14 n.s.	5.44 n.s.
Epinephelus costae	8.58 **	10.00 *	3.14 n.s.	13.21 **	6.08 n.s.
Mycteroperca rubra	14.29 ***	6.67 n.s.	2.95 n.s.	8.43 *	26.40 ***

Table IV. - Number of dusky groupers (*Epinephelus marginatus*) of different size (total length) classes (small: < 40 cm; medium: 40-60 cm; large: 61-80 cm; very large: > 80 cm) observed in the sampling periods for each coast of the islet. The surveyed area (x 10^3 m^2) per sector is in parentheses. *[Nombre d'*Epinephelus marginatus *de différentes classes de taille (longueur totale) (petite < 40 cm; moyenne 40-60 cm; grande 61-80 cm; très grande > 80 cm) observés pendant les périodes de recensement pour chaque côte de l'îlot. La zone d'échantillonnage par secteur (x 10^3 m^2) est entre parenthèses.]*

Year	Month	Size class	Coast				Total
			SW (15.0)	SE (15.8)	NE (9.0)	NW (18.2)	
2002	June	small	1	1	0	0	2
		medium	5	5	3	2	15
		large	3	2	0	3	8
		very large	6	3	0	2	11
	July	small	0	0	4	0	4
		medium	2	7	3	7	19
		large	3	5	1	3	12
		very large	0	4	0	4	8
	August	small	0	5	4	1	10
		medium	5	3	2	4	14
		large	4	2	1	1	8
		very large	3	4	0	6	13
	September	small	0	1	0	1	2
		medium	4	3	2	2	11
		large	4	0	0	2	6
		very large	4	3	0	3	10
2003	June	small	0	0	0	1	1
		medium	2	1	0	1	4
		large	1	1	4	2	8
		very large	2	1	1	2	6
	July	small	0	0	0	0	0
		medium	3	5	7	1	16
		large	4	8	3	1	16
		very large	7	2	0	1	10
	August	small	0	0	0	1	1
		medium	4	9	1	1	15
		large	3	2	3	1	9
		very large	4	2	0	2	8
	September	small	0	1	0	1	2
		medium	3	4	4	7	18
		large	3	2	1	1	7
		very large	2	3	0	1	6

Data analysis

To test for differences in the abundance of the three species in relation to time (between and within sampling

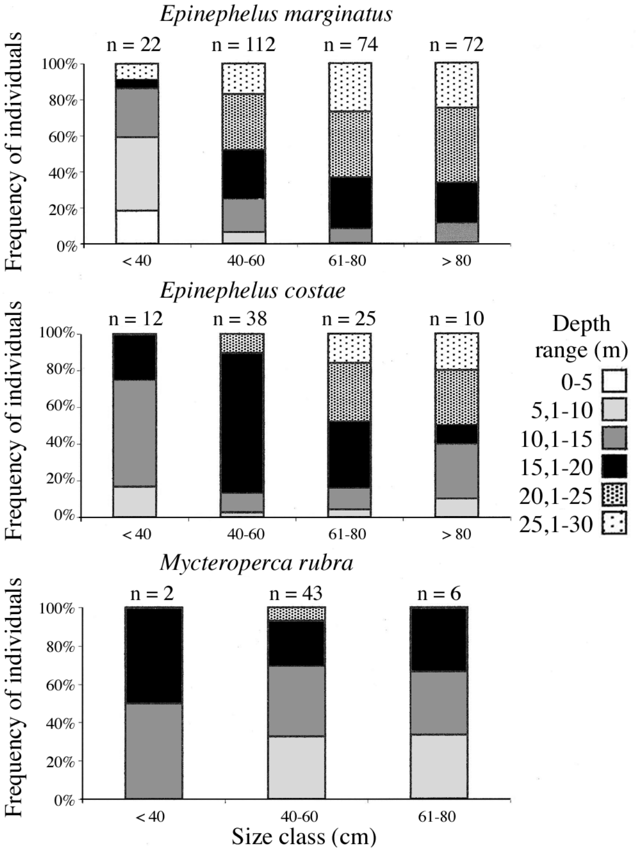


Figure 2. - Size frequency distributions of *Epinephelus marginatus*, *E. costae* and *Mycteroperca rubra* in relation to depth. n = total number of individuals. *[Distribution des fréquences de taille d'*Epinephelus marginatus, E. costae *et* Mycteroperca rubra *en fonction de la profondeur. n = nombre total d'individus.]*

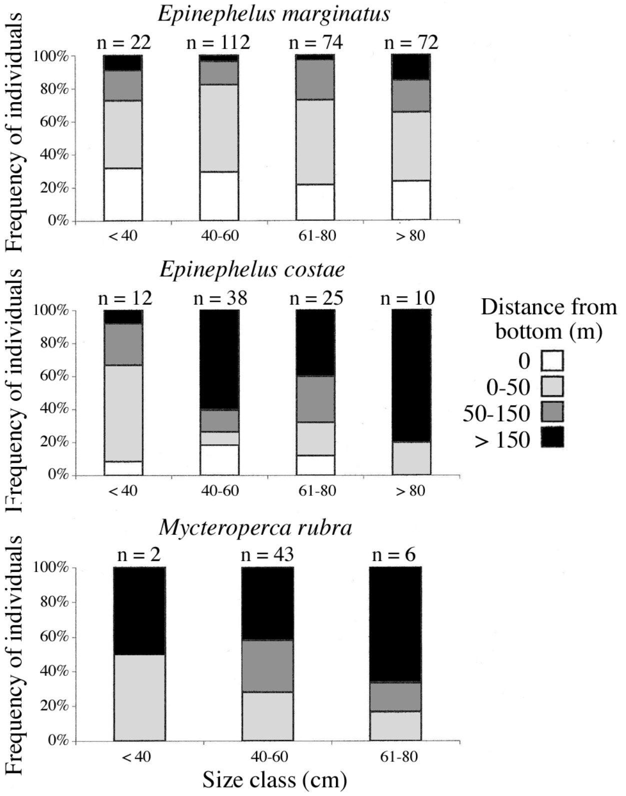


Figure 3. - Size frequency distributions of *Epinephelus marginatus*, *E. costae* and *Mycteroperca rubra* in relation to distance from bottom. n = total number of individuals. *[Distribution des fréquences de taille d'*Epinephelus marginatus, E. costae *et* Mycteroperca rubra *en fonction de la distance du fond. n = nombre total d'individus.]*

year) and space (among coasts of the islet) a χ^2 analysis was applied. Abundance data were standardized in order to account for the differences in sampled area among the islet coasts. The variation of the size-frequency distribution of groupers over time and space was analysed by a χ^2 test. The analysis was performed only on *E. marginatus*, due to the scantiness of records of the other species. To test for differences in the size-frequency distribution of the three species in relation to depth, distance from bottom and reaction to diver a χ^2 analysis was performed. Prior to run the analyses, the size of individual fish was assigned to one of four size classes (small: < 40 cm; medium: 40-60 cm; large: 61-80 cm; very large: > 80 cm).

The influence of abiotic and biotic variables on the micro and macrohabitat requirements of groupers was studied by correspondence analysis (CA) (Benzecri and Benzecri, 1976; Greenacre, 1984). The variables included in the analysis are listed in table I. The contingency tables were constructed by splitting each variable in different categories (numerically ordered) and by using a binary code (0 or 1). For each species, data referred to the micro and macrohabitat characterization were separately analysed. The distribution pattern of each species sample was analyzed by a χ^2 test, in order to test if the specimens were equally distributed along the axes. In *E. marginatus* and *E. costae* a χ^2 test was also used to analyze the distribution pattern of specimens by size class.

RESULTS

Species abundance and distribution

Data collected on grouper abundance are summarized in table II. The grouper assemblage was numerically dominated by *Epinephelus marginatus*, whereas *Mycteroperca rubra* was represented by the lowest number of individuals, at least during the 2002 surveys. The abundance of *E. marginatus* peaked generally in the mid-summer, namely in July or August, whilst in *M. rubra* a specific trend of variation was not so evident. The number of censused individuals of *Epinephelus costae* decreased progressively from June to September 2002, whereas it fluctuated during summer 2003. The presence of *E. marginatus* was fairly constant

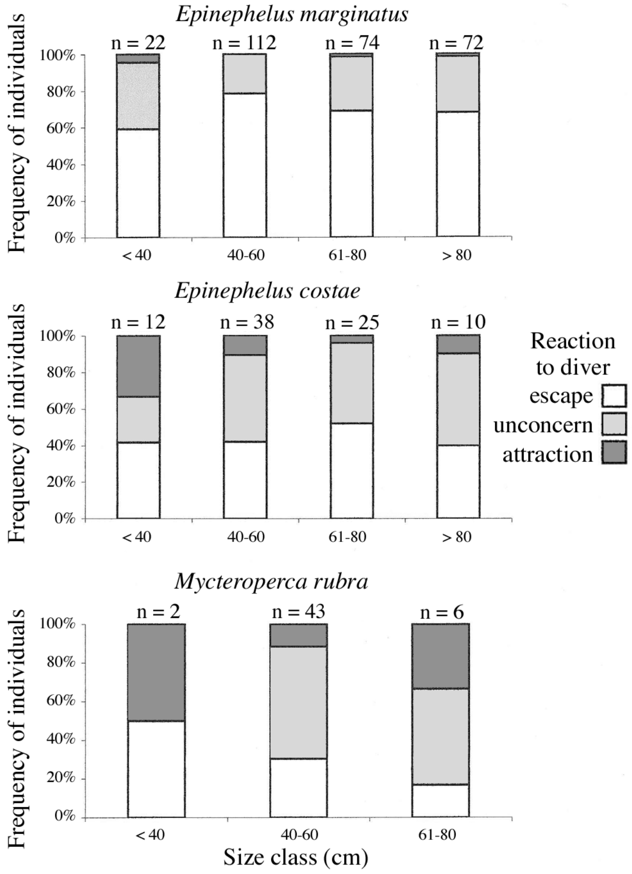


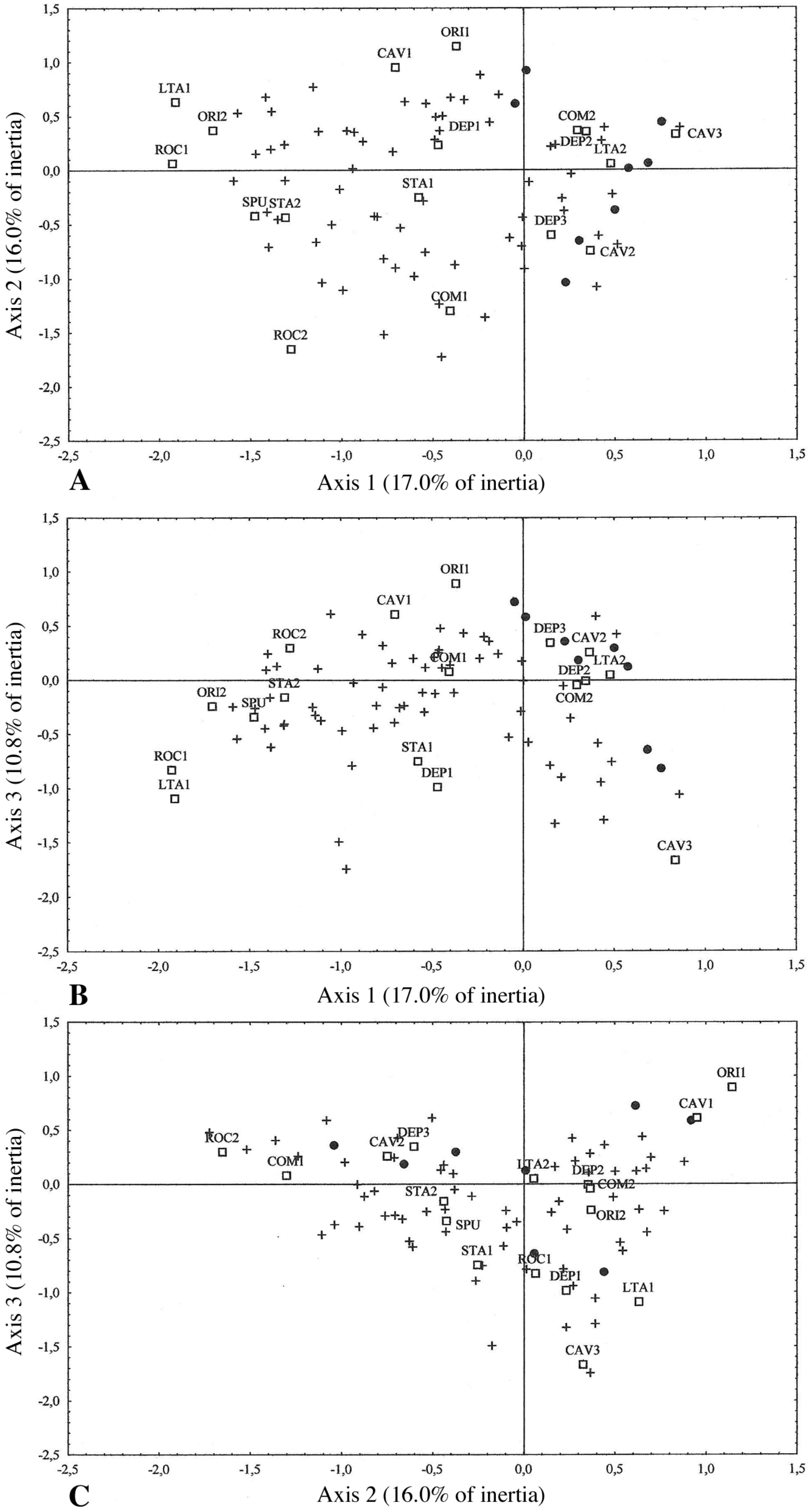
Figure 4. - Size frequency distributions of *Epinephelus marginatus*, *E. costae* and *Mycteroperca rubra* in relation to reaction to diver. n = total number of individuals. *[Distribution des fréquences de taille d'*Epinephelus marginatus, E. costae *et* Mycteroperca rubra *en fonction de la réaction au plongeur. n = nombre total d'individus.]*

throughout the coastal area of the islet, regardless to sampling period. Conversely, *M. rubra* was almost exclusively recorded along the western sectors. As demonstrated by χ^2 analyses, some differences in grouper abundance among sampling periods and areas (islet coasts) were detected (Tab. III). The interannual difference in grouper abundance was highly significant and mainly related to the unbalanced distribution of *M. rubra*. *M. rubra* was very uncommon in the first sampling year, whereas *E. costae* was more abundant in 2002 than in 2003 surveys. Monthly variation in grouper abundance was not significant during the first year, except for *E. costae* which displayed a marked decline from June to September. In the second sampling year, significant differences over months were observed at the assemblage (all species combined) level. As also suggested by the analysis on single species, these differences were mostly accounted for by the distribution of *E. marginatus*, which was in June less abundant than expected. During the first and especially the second sampling year, grouper assemblage was not evenly distributed around the coast of the islet. In summer 2002, the species relative abundance in the south-western and south-eastern coasts gave the largest contribution to the observed variation. The south-western coast was highly preferred both by *E. costae* and *M. rubra*, the south-eastern coast by *E. marginatus*. In summer 2003, the observed differences relied mainly upon *M. rubra*, which was particularly abundant in the north-western coast but nearly unrecorded in the south-eastern one.

Size distribution of *E. marginatus*, and relationships between grouper size and depth, distance from bottom and reaction to diver

The size range (TL) of observed groupers was 15-120 cm for *E. marginatus*, 20-110 cm for *E. costae* and 35-80 cm for *M. rubra*. The number of dusky groupers by size classes is reported in table IV. Regardless to sampling period, the medium sized individuals were generally the most numerous, followed by those of large and very large size. The size distribution of *E. marginatus* did not show significant differences with respect to sampling year or month (within year), whereas it did in relation to the islet coasts in the 2002 survey ($\chi^2 = 25.6$, $p < 0.042$). The highest contributions to the observed variation were given by the small and very large sized individuals, which were in the north-eastern coast respectively more and less abundant than expected. The size frequency distributions of the three species in relation to depth are reported in figure 2. The size distributions of *E. marginatus* and *E. costae* over depth varied significantly ($\chi^2 = 127.4$, $p < 0.0001$ and $\chi^2 = 42.1$, $p < 0.0017$, respectively). In *E. marginatus*, the observed differences were mainly related to the small sized individuals, which were above 10 m depth more abundant than expected. In *E. costae*, the highest contributions to the total variation were accounted for by the small and medium sized individuals, which were more abundant than expected in the 10.1-15 and 15.1-20 depth range, respectively. As a whole, in both species there was a shift of groupers toward deeper waters with increasing size. No significant differences were detected in the size frequency distribution with depth of *M. rubra*, which occurred at narrower depth range than the other species.

The distribution of different sized individuals of *E. costae* showed significant differences ($\chi^2 = 25.5$, $p < 0.04$) with respect to distance from bottom (Fig. 3). The small sized individuals, which mostly occurred close to the bottom (0-50 cm), were the main responsible of the observed variation. No significant relationship between fish size and distance from bottom was conversely evidenced in *E. marginatus* and *M. rubra*. Regardless to fish size, the majority of dusky grouper was observed resting on or close to bottom. Conversely, both *E. costae* and *M. rubra* swam preferentially far from the bottom. The kind of reaction to diver had no significant relationship with grouper size in all the investigated species (Fig. 4). The most of dusky grouper escaped from the diver, whereas in *E. costae* and *M. rubra* more than 50% of the individuals remained unconcerned in front of or was attracted by the diver.



Habitat preferences

In the correspondence analyses on the habitat preferences of groupers, the distribution pattern of each species was evaluated on the first three axes, but only the most meaningful axes (in terms of specimens distribution) are shown. The results on the microhabitat preferences of *E. marginatus* are reported in figure 5. A significant shift of medium ($\chi^2 = 9.1$; $p < 0.01$), large ($\chi^2 = 17.5$; $p < 0.001$) and very large individuals ($\chi^2 = 34.7$; $p < 0.001$) toward the positive side of axis 1 suggested a preference for substrata almost entirely covered by long turf algae (LTA2) rather than for bare rocks (ROC1) mixed with few long turf algae (LTA1) and sponges (SPO1) (Fig. 5A, B). Conversely, the small dusky groupers were mainly located in the negative side of axis 1 ($\chi^2 = 8.9$; $p < 0.01$). Substrate complexity mostly contributed to the distribution pattern along axis 2. As suggested by the unbalanced distribution toward the positive side of the axis ($\chi^2 = 8.2$; $p < 0.01$), *E. marginatus* preferred bottoms with high vertical relief (COM2) (Fig. 5A, C). The observed pattern of distribution along axis 2 relied mainly upon the very large specimens ($\chi^2 = 5.5$; $p < 0.05$). According to their position along axis 3, the majority of medium ($\chi^2 = 9.1$; $p < 0.01$), large ($\chi^2 = 15.6$; $p < 0.001$) and very large individuals ($\chi^2 = 54.5$; $p < 0.05$) was observed near upward oriented cavities (ORI1 and CAV1) rather than on convex substrata (CAV3) (Fig. 5B, C).

As for the macrohabitat preferences of *E. marginatus*, no significant shift along the axes was detected (Fig. 6A, B).

Figure 5. - Results of correspondence analysis on the microhabitat preferences of *Epinephelus marginatus*. Variable codes and categories as in table I. +: individuals; •: groups of 10 or more individuals; □: variables. *[Résultats de l'analyse des correspondances sur les préférences de microhabitat d'*Epinephelus marginatus*. Les codes et les catégories des variables sont indiqués dans le tableau I.]*

Along axis 1, which was mainly related to the bottom topography, the number of individuals on rocky plateau (PLA2) was comparable to that observed on boulders (BOU2), frequently associated with a high sheltering degree (SHD3). As demonstrated by the balanced distribution of individuals along axes 2 and 3, there was no preference in *E. marginatus* in terms of bottom slope.

In the analyses on the microhabitat variables of *E. costae*, axes 1 and 2 were the most meaningful (Fig. 7A). A significant shift toward the negative side of axis 1 ($\chi^2 = 21.7$; $p < 0.001$) and the positive side of axis 2 ($\chi^2 = 12.8$; $p < 0.001$) indicated the preference for flat habitat (CAV2), located between 14 and 22 m depth (DEP2). All the remaining individuals were observed either near upward oriented cavities (ORI1 and CAV1) at the shallower depth range (DEP1) or on convex substrata (CAV3) and below 22 m depth (DEP3). Significant differences in the distribution of *E. costae* along axis 1 were observed in both medium ($\chi^2 = 20.6$; $p < 0.001$) and large specimens ($\chi^2 = 9.0$; $p < 0.01$), whereas along axis 2 they were detected only in medium individuals ($\chi^2 = 30.4$; $p < 0.001$).

E costae displayed no specific requirements in terms of macrohabitat, as suggested by the balanced distribution of the individuals of each size class along the axes. The number of individuals on the positive side of axis 1, which was mainly represented by sub-horizontal habitats (SLO1) with few boulders (BOU1), was comparable to that observed in the negative one, which was characterized by sloping bottoms (SLO2) covered by a lot of boulders (BOU2) (Fig. 7B). No differences were also observed along axis 2, where bottom topography (boulders versus rocky plateau) mostly contributed to the total inertia (Fig. 7B). The choice of microhabitat in *M. rubra* was principally affected by the presence/absence of cavity. Looking at the distribution pattern along axis 3, the majority of groupers ($\chi^2 = 12.2$; $p < 0.001$) preferred flat bottoms (CAV2), instead of convex or concave substrata (CAV3 and CAV1) (Fig. 8A). Conversely, there was no significant difference in the mottled grouper distribution in relation to depth, which was the most important variable along axis 1. At macrohabitat level, this species showed preference for rocky plateau (PLA2 and SLO1) rather than sloping bottoms (SLO2) with many boulders (BOU2) ($\chi^2 = 4.4$, $p < 0.05$ and $\chi^2 = 8.6$, $p < 0.01$ for the axes 1 and 2, respectively) (Fig. 8B). The significant shift of mottled groupers toward the positive side of axis 3 ($\chi^2 = 26.8$; $p < 0.001$) confirmed that boulder habitat was not appreciated by *M. rubra* (Fig. 8C).

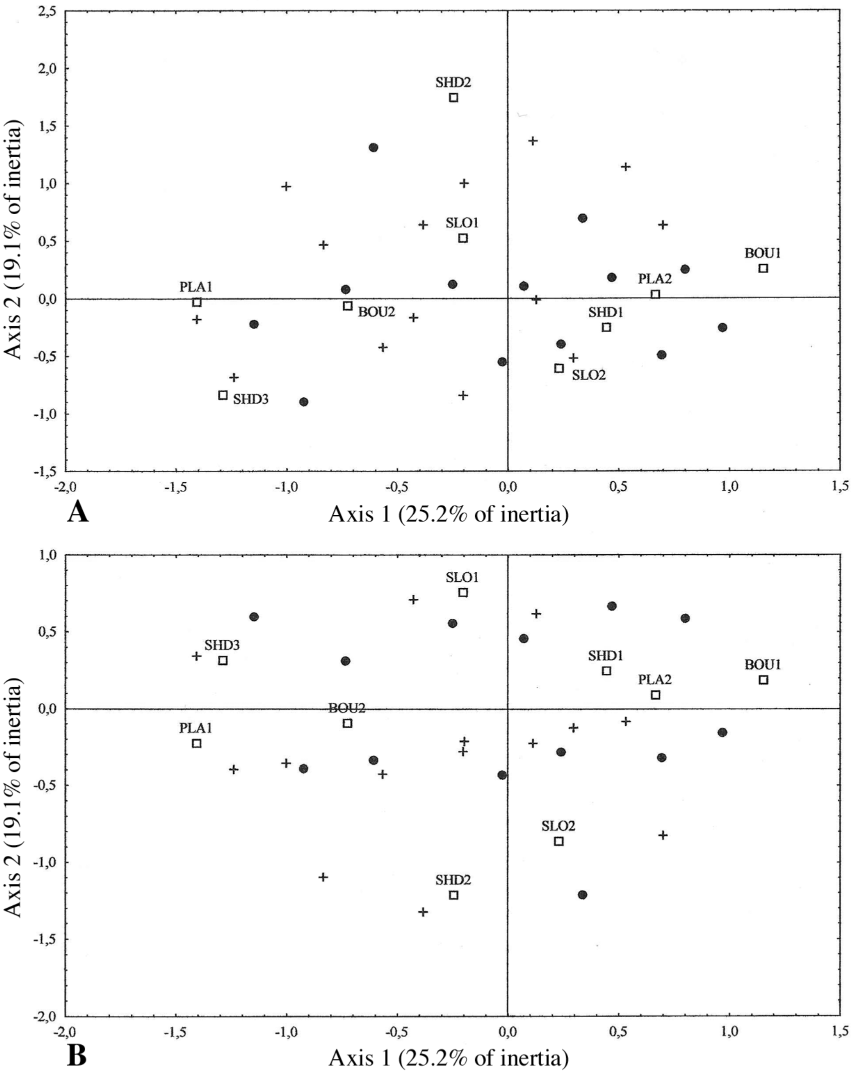


Figure 6. - Results of correspondence analysis on the macrohabitat preferences of *Epinephelus marginatus*. Variable codes and categories as in table I. +: individuals; •: groups of 10 or more individuals; □: variables. *[Résultats de l'analyse des correspondances sur les préférences de macrohabitat d'*Epinephelus marginatus*. Codes et catégories : tableau I.]*

DISCUSSION

Species abundance and distribution

As demonstrated by the present results, the coastal area around the Scoglio del Medico hosted during summer a diversified and abundant grouper assemblage. The dusky grouper *Epinephelus marginatus* can be considered fully established in this area, considering its commonness through time and space and the well structured population. The other species of grouper were generally less represented and their density varied markedly depending on sampling period. Both *Epinephelus costae* and especially *Mycteroperca rubra* were not evenly distributed along the islet coasts. These species were mostly recorded in the western sectors, which were the most exposed to the prevailing wave direction. The large quantity of food usually associated to the strong hydrodynamism in exposed zones, such as off promontories, may promote gatherings of predator fish such as groupers (Coll *et al.*, 1995; Pelaprat, 1999). In *E. costae* and *M. rubra*, a clear pattern of density variation during summer was not evidenced. Conversely, the abundance of *E. marginatus* displayed a normally distributed trend of variation. In agreement with other investigations, the largest number of dusky grouper was observed in July and August, the warmest months during which the apex of reproductive activity generally occurs (Zabala *et al.*, 1997a, 1997b; Culioli and Quignard, 1999; Louisy and Culioli, 1999; Mathieu-Tissot, 1999). In NW Mediterranean, the actual spawning of dusky grouper has been rarely observed (Zabala *et al.*, 1997b; Louisy and Culioli, 1999; Pelaprat, 1999). It generally occurs between late June and early August and lasts 7-15 days, but some observations in central Mediterranean suggest a longer spawning period (Marino *et al.*, 2001). Around the Scoglio del Medico, the presence of very large specimens showing the silver striked colour pattern typical of the dominant males (Zabala *et al.*, 1997a, 1997b) would suggest the occurrence of spawning events, although no direct observation of them was obtained. The density of *E. marginatus* (3-7 individuals/ha) observed around the Scoglio del Medico was comparable with that reported by Lenfant *et al.* (2003) in the Cerbère-Banyuls Marine Reserve (1.5^{-3} and 10 individuals/ha in the partially and totally protected areas, respectively).

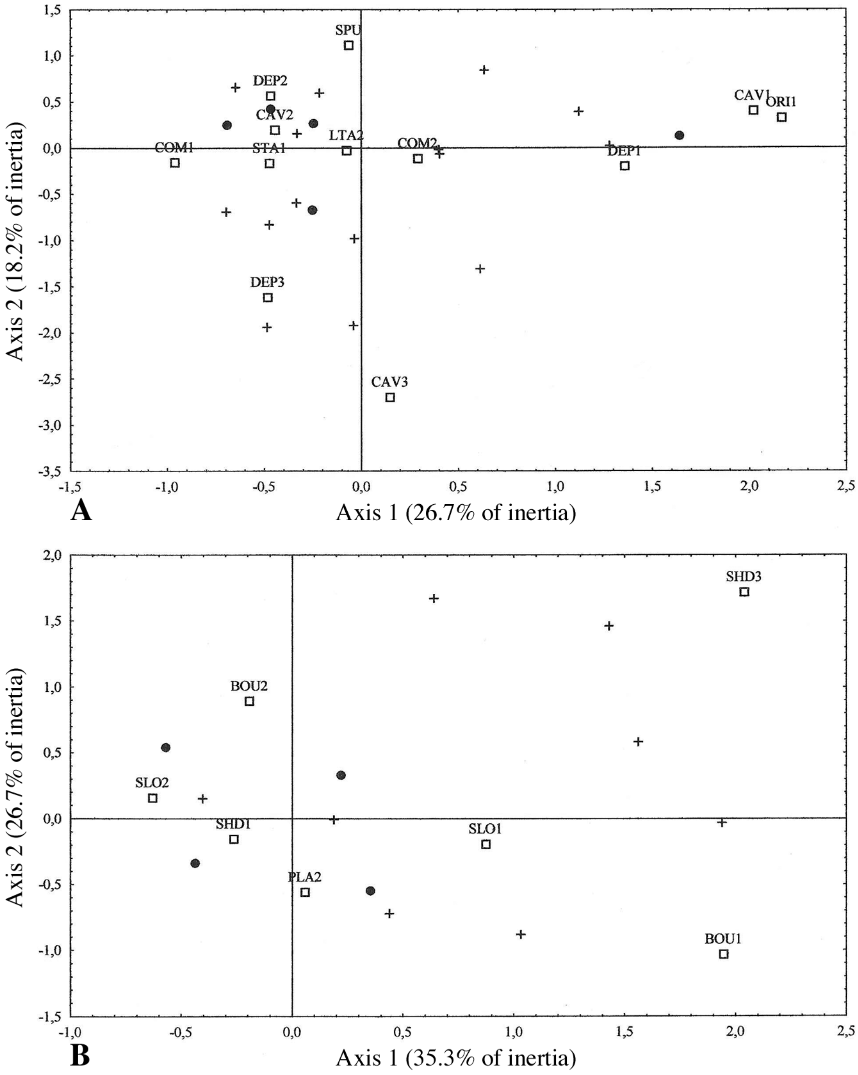


Figure 7. - Results of correspondence analysis on the micro (**A**) and macrohabitat (**B**) preferences of *Epinephelus costae*. Variable codes and categories as in table I. +: individuals; •: groups of 6 or more individuals; □: variables. *[Résultats de l'analyse des correspondances sur les préférences de micro- (**A**) et macrohabitat (**B**) d'*Epinephelus costae. *Codes et catégories : tableau I.]*

Size distribution of *E. marginatus*, and relationships between grouper size and depth, distance from bottom and reaction to diver

Our data on the size structure of *E. marginatus* are close to those collected in other Mediterranean rocky shores. The dominance of medium sized individuals was observed in other marine protected areas, such as the Cerbère-Banyuls Marine Reserve (Mathieu-Tissot, 1999; Lenfant *et al.*, 2003) and the Natural Reserve of the strait of Bonifacio (Culioli and Quignard, 1999) and in areas open to fishing (Derbal and Kara, 1995). In the Port-Cros National Park, the large sized individuals were the most numerous (Chauvet and Francour, 1989), but the number of small and medium sized specimens increased markedly since the late 90s (Harmelin and Robert, 2001). In the Cabrera National Park, Reñones *et al.* (1999) suggested the existence of a self-recruiting population of dusky grouper, due to the dominance of small and medium sized individuals (95% of total sample). Juveniles dusky grouper were not very common around Scoglio del Medico, likely due to the low sheltering degree offered by the islet coastline. Conversely, during earlier investigations they were recorded in large number along the shallow (0-3 m) rocky reefs of the island, often in small bays sheltered from the open sea (Vacchi *et al.*, 1999; La Mesa *et al.*, 2002).

Dealing with the distribution of *E. marginatus* with depth, a positive correlation between the bathymetric range and fish size has been reported by many authors (Chauvet, 1991; Derbal and Kara, 1995; Francour and Ganteaume, 1999; Harmelin and Harmelin-Vivien, 1999; Harmelin and Robert, 2001). This general trend is especially evident in areas impacted by spearfishing, whose main effect is to eliminate adult groupers from shallow-waters bottoms (Derbal and Kara, 1995; Coll *et al.*, 1999). In the present study, a positive relationship between grouper size and depth was observed both in *E. marginatus* and *E. costae*. Along the investigated depth range, the distribution of *E. marginatus*, *E. costae* and *M. rubra* largely overlapped.

The habit to rest on or to swim close to the bottom, which was very frequently exhibited by dusky grouper regardless to fish size, was displayed in *E. costae* by the small sized individuals only. Medium and large sized individuals of *E. costae* and *M. rubra* showed conversely more pelagic habits, being often recorded far from bottoms and swimming against the current. This could be interpreted as a higher level of dependence of juveniles on the shelter opportunities offered by sea bottom. As pointed out by Harmelin and Robert (1992), the survival of juvenile dusky groupers is strictly related with shelter availability. In a recent study on

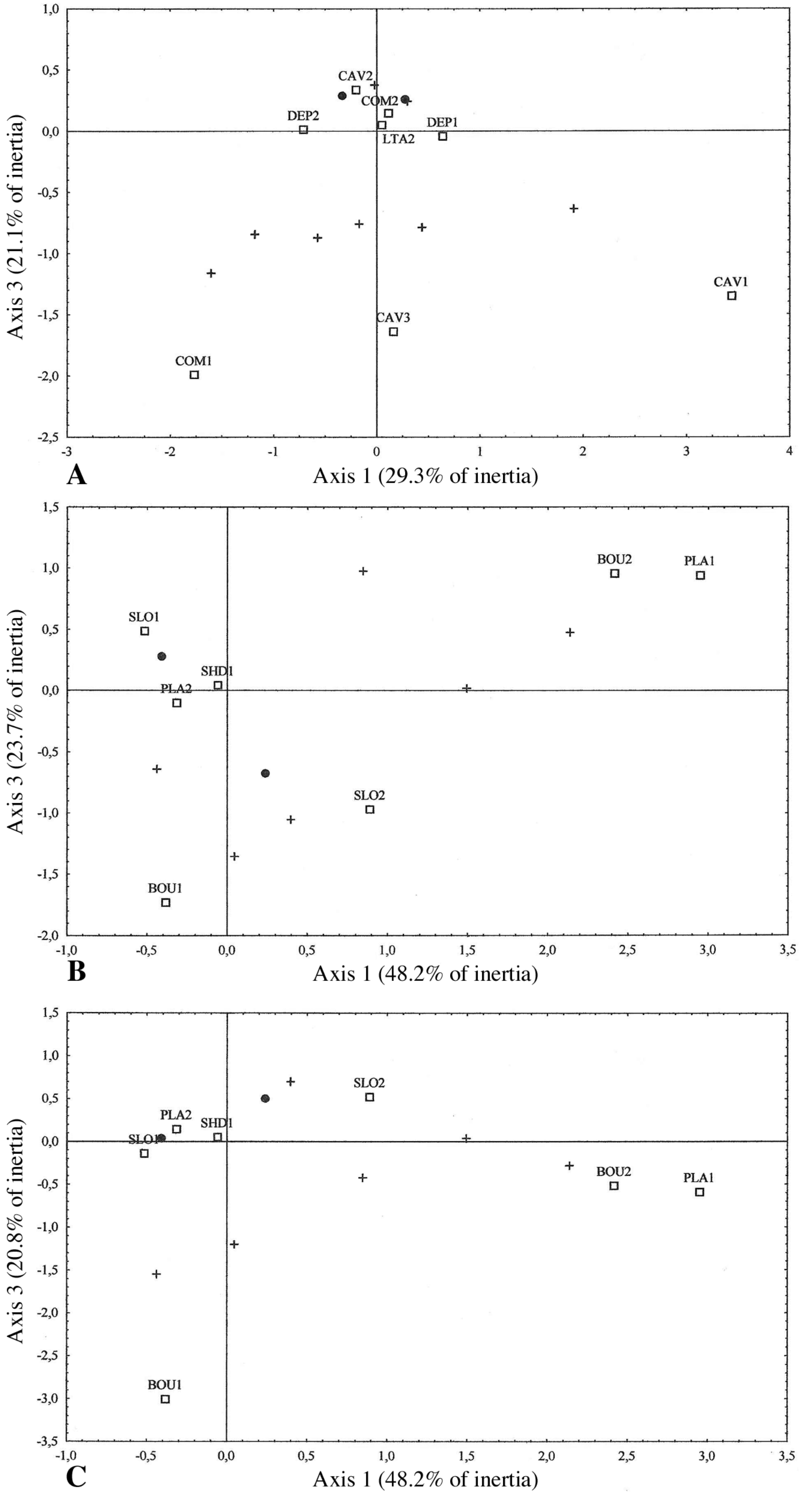


Figure 8. - Results of correspondence analysis on the micro (**A**) and macrohabitat (**B**, **C**) preferences of *Mycteroperca rubra*. Variable codes and categories as in table I. +: individuals; •: groups of 10 or more individuals; □: variables. *[Résultats de l'analyse des correspondances sur les préférences de micro- (**A**) et macrohabitat (**B**, **C**) de* Mycteroperca rubra. *Codes et catégories : tableau I.]*

the habitat preference of juvenile dusky groupers, most individuals were observed very close to restricted microenvironments, such as cavities or crevices, which often represented their own shelter (La Mesa *et al.*, 2002). Some observations collected in coral reef habitats referred to juvenile groupers as cryptic fish, closely associated with the bottom, not straying far from crevices (Smith, 1961; Nagelkerken, 1979).

In the present work, the behavioural response of dusky grouper to diver presence seemed substantially independent of fish size. Such an outcome was not in agreement with literature data. According to Mathieu-Tissot (1999), juveniles escaped from the diver more frequently than medium and large sized groupers, whereas the opposite situation was reported by Derbal and Kara (1995). On the other hand, a common finding was that the majority of groupers escaped from the diver. A slighlty different pattern of reaction was observed in *E. costae* and *M. rubra*, which seemed less suspicious towards the observer than *E. marginatus*. This behavioural trait could be detrimental to their survival in areas open to spearfishing and, if confirmed by further investigations, would support the usefulness of marine protected areas for the conservation of these species.

Habitat preferences

For *E. marginatus*, medium to very large individuals preferred rocky reef with dense algal canopy (especially long turf algae) and high complexity. On the contrary, small dusky groupers were more frequently associated to bare rock substrata. In the dusky grouper juveniles, the shelter opportunities provided by small cavities and crevices should be better than those offered by a dense algal coverage. In the Nassau grouper *Epinephelus striatus*, a positive and significant relationship between amount of macroalgae and density of post-settlement individuals has been demonstrated (Eggleston, 1995). In the Florida Keys, the densities of some grouper species were significantly influenced by some abiotic features of reefs, generally associated with the sea-bottom structural complexity (Sluka *et al.*, 1998, 2001). A group of species composed by *Cephalopholis cruentata, Mycteroperca bonaci* and *E. striatus* preferred high to moderate relief habitats, whereas *E. guttatus* was more abundant in low-relief habitat. In *C. cruentata* there was also a relationship between fish size and height of relief, the larger groupers being observed in areas of higher vertical relief than smaller ones (Sluka *et al.*, 1998, 2001). Our results demonstrated that such a relationship is likely to occur also in *E. marginatus*.

In the present study, both *M. rubra* and, except for the small sized individuals, *E. costae* showed no interest for uneven substrata with cavities and crevices. As suggested by their benthopelagic behaviour, the need for shelter in these species was not so urgent as in *E. marginatus*. Neither *E. marginatus* nor *E. costae* displayed specific requirements in terms of macrohabitat. The habitat choice in both species was then principally based on some biotic and abiotic features that characterise the environment at small spatial scale (microhabitat), in a similar way to what has been observed in juvenile dusky groupers (La Mesa *et al.*, 2002). On the contrary, *M. rubra* showed preference towards some macrohabitat features, such as bottom topography and slope (rocky plateau with gentle slope instead of boulder field).

In conclusion, our results give new insight into the habitat requirements of three sympatric grouper species, such as *E. marginatus*, *E. costae*, and *M. rubra*. The main interspecific differences relied substantially upon a stronger relationship with bottom features of *E. marginatus* compared with the other groupers. As for the habitat preferences of *E. costae* and *M. rubra*, the scanty records collected here and, primarily, the lack of previous researches, make further investigations advisable, in order to verify the generality of our findings.

Acknowledgements. - We are grateful to the anonymous referees for their suggestions for improving the manuscript. The research was supported by funds provided by the Natural Marine Reserve of Ustica Island.

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Reçu le 24 février 2006.
Accepté pour publication le 16 octobre 2006.